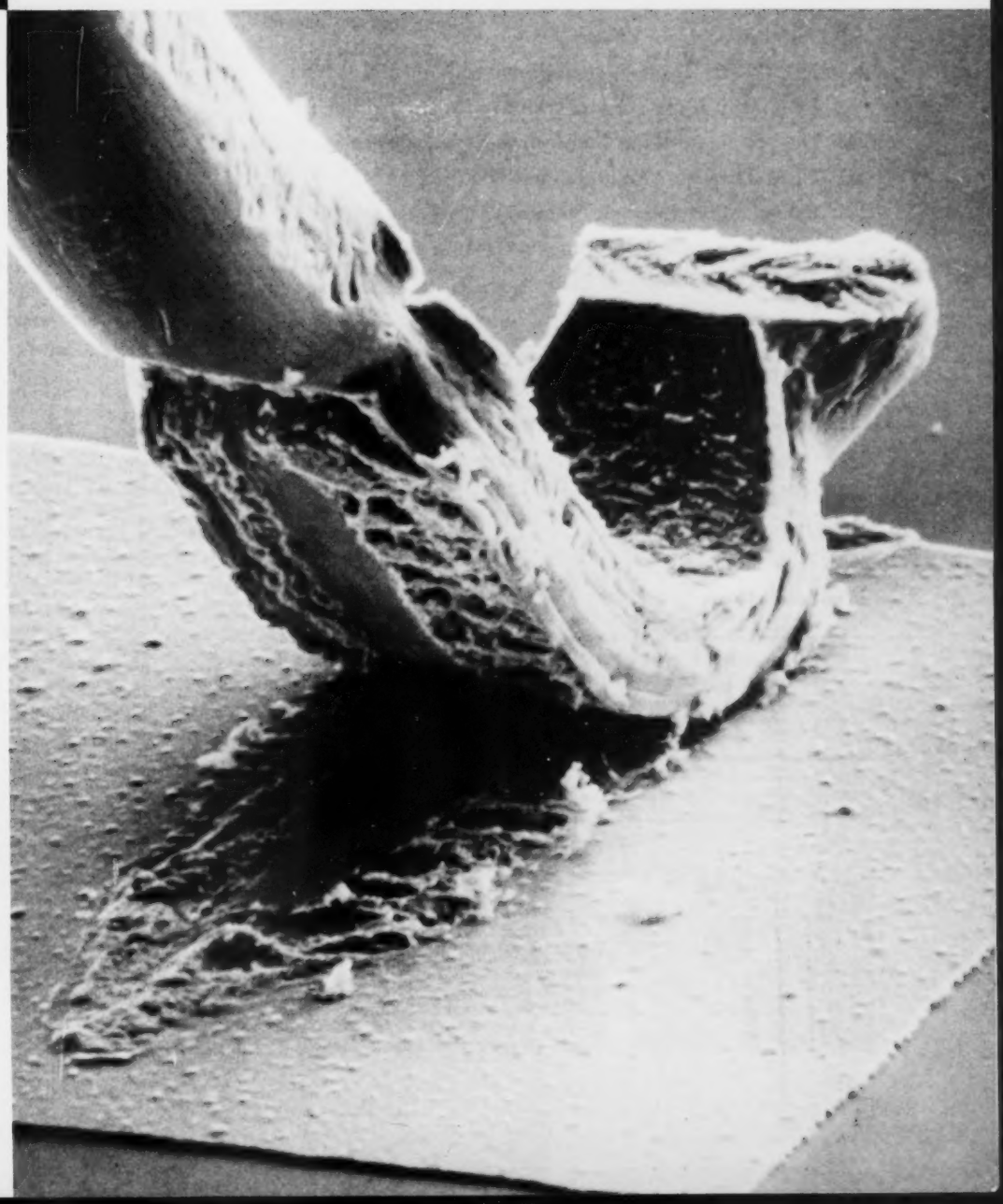
A UNITED STATES DEPARTMENT OF COMMERCE PUBLICATION

OCTOBER 1971

U.S.

NATIONAL BUREAU OF STANDARDS

Technical News Bulletin



UNITED STATES DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS
Technical News Bulletin
October 1971 / VOL. 55, NO. 10 / ISSUED MONTHLY

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Nat. Bur. Stand. (U.S.) Tech. News Bull.
CODEN: NBSTA 55(10) 237-260 (1971)
Superintendent of Documents Catalog No. C13.13:55/10
Library of Congress Catalog No. 25-265227

Cover: A lead bonded to a semiconductor has been partially lifted, showing, in this scanning electron microscope micrograph, an area of good bonding surrounding a typically unbonded area. See page 248 for a description of the NBS study of such bonds. (Magnification approximately 1,000x)

U.S. DEPARTMENT OF COMMERCE
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The National Bureau of Standards serves as a focal point in the Federal Government for assuring maximum application of the physical and engineering sciences to the advancement of technology in industry and commerce. For this purpose, the Bureau is organized as follows:

The Institute for Basic Standards

The Institute for Materials Research

The Institute for Applied Technology

Center for Radiation Research

Center for Computer Sciences and Technology

The TECHNICAL NEWS BULLETIN is published to keep science and industry informed regarding the technical programs, accomplishments, and activities of NBS.

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Annual subscription: Domestic, $3; foreign, $4; single copy, 30 cents. Use of funds for printing this publication approved by the Director of the Bureau of the Budget (June 22, 1971).

HOT-HOLE ELECTRON CASCADES IN FIELD EMISSION

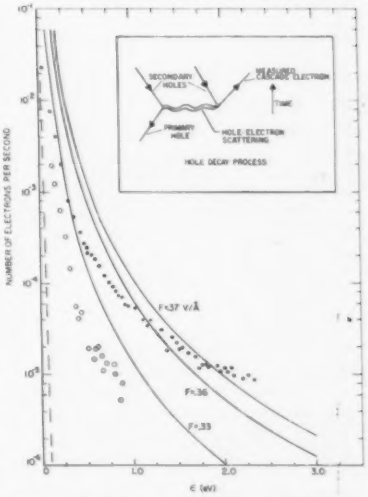
HIGH ENERGY ELECTRONS PRODUCED BY THE FIELD EMISSION CASCADE PROCESS have been observed for the first time and theoretically explained at the Bureau by J. W. Gadzuk and E. W. Plummer,[1] using the basic Simpson-Kuyatt spherical deflection energy analyzer specially adapted to a field emission source by C. E. Kuyatt. It was found that the rate limiting factor for the production of excited electrons in a metal is the quasi-particle lifetime for excited states of the solid. Thus measurement and interpretation of the high energy tail of a field emission total energy distribution plot gives direct knowledge of the many-body interactions in matter. Such interactions are of importance in analyses of the electronic properties of metals and of radiation damage of materials.

Electron field emission occurs when a field of nearly 30 million volts per centimeter is applied to a metal tip whose radius is about 1000 Å. The field reduces the electron barrier at the surface, allowing the electrons to quantum mechanically tunnel out of the metal. As an electron leaves the metal, an electron deficiency, known as a "hot hole," remains. The energetic hot hole then undergoes inelastic collisions with the electrons in the metal conduction band, producing several slightly excited Auger electrons for each initial hot hole. The sum total of all such processes has been called a hot-hole cascade, since the process was initiated by the extraction of the electron or in other words, by the injection of the hot-holes. The cascade products can then tunnel from the metal and be observed as high energy electrons above the Fermi energy of the metal. These are few in number and are recorded by the very sensitive energy analyzer which plots the total energy distribution of current density versus energy. This study has been the first solid state tunneling experiment in which such Auger tails have been observed.

EXPERIMENT

In these measurements a fine tungsten wire is etched to a point of about 1000 Å radius, and used as the emitter of electrons in electron field emission microscopy. A field of nearly 30 million volts per centimeter is achieved at the surface of the emitter by applying a few thousand volts to a fluorescent screen, perpendicular to the point. At such a high field the electrons tunnel elastically from within the metal tip into the vacuum to produce a stereographic projection of the nearly hemispherical end cap of the tip on the screen. Contrast in the screen's image is due to crystallographic variations in the electronic work function—the minimum energy required for an electron to escape from a given surface.

The plane to be studied is positioned over a small hole in the screen (probe hole) and the electrons passing through the probe hole are energy analyzed. The analyzer is composed of retarding lenses, designed by C. E. Kuyatt, and a 135° spherical deflection analyzer of the Simpson-Kuyatt type. It is capable of current measurements over eight orders of magnitude at a resolution of at least 0.020 eV.

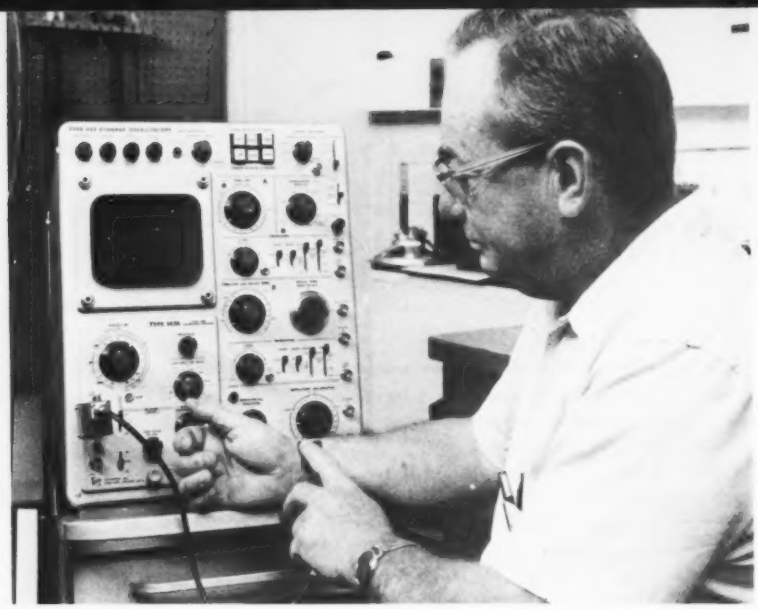


NBS made the first observations of a hot hole electron cascade process in this field emission energy distribution plot of the (111) plane of tungsten at 78 K for various values of applied electric field, F. With the Fermi level at $\epsilon = 0$, the dashed line shows the high energy tail theoretically expected from usual thermal effects. The rather striking departures from the thermal curve of the solid lines show electron energy distributions predicted for hot-hole electron cascades and the experimentally determined points, for fields of .33 and .37 volts per angstrom, yields evidence of the cascade produced electrons. In the figure, all curves have been normalized to one at the Fermi energy. Insert: Diagram illustrating one step in the hole decay process in which a hot-hole scatters from the electron gas, producing two holes and one hot secondary electron.

The results of this work resulted from data initially obtained in field emission studies of surface state electrons.[2]

[1] For more complete details, see Gadzuk, J. W., and Plummer, E. W., Hot-hole—electron cascades in field emission from metals, Phys. Rev. Letters **26**, No. 2, 92-95 (Jan. 1971).

[2] Surface states of electrons in metals, Nat. Bur. Stand. (U.S.), Tech. News Bull. **55**, No. 6, 153 (June



Seymour Edelman applies an experimental piezoelectric probe to his wrist to reproduce his pulse on an oscilloscope. This is one application for transducers made from treated polymer films.

THE PIEZOELECTRIC EFFECT IN POLYMERS

THE PIEZOELECTRIC EFFECT IN SOME POLYMER FILMS, under study at the NBS Institute for Applied Technology, has been shown to be the result of rolling during processing. Physicists Julius Cohen and Seymour Edelman, of the Institute's electronic technology laboratories, found in tests on rolled polyvinylchloride film and cast polyvinylfluoride film that the piezoeffect is present following rolling in processing or in the laboratory and is lost with heating.[1] Research is continuing on the many interesting electrical characteristics of polymers and their application in such fields as biomedical instrumentation, underwater sound transducers, and infrared detection.

PIEZOELECTRICITY IN POLYMERS

The Institute's first research on the piezoelectric effect in polymers (previously reported by others in the literature) was on piezoelectricity in elastomers—rubberlike materials—used as damping layers in "shakers"—devices used to excite accelerometers. Materials tested included fluorocarbon, a polymeric amide, polystyrene, a filled phenolic resin, an epoxy resin, and natural rubber. Some of these materials were found to have a weak piezoresponse; the first NBS efforts were to increase this response by applying polarizing voltages during hardening of the material.[2]

By rolling this polyvinylchloride tape thinner, Steven Roth gives it anisotropic piezoelectric characteristics that will enable samples from it to be used as piezoelectric devices.

Subsequent efforts to enhance the piezocharacteristic used ac voltages with the dc polarizing voltages applied to specimens cut from rigid polyvinylchloride (PVC) sheets. Piezoelectric strain moduli of 0.6×10^{-12} were achieved.[3]

Much higher levels of piezoresponse have since been found in flexible PVC sheet material, tested in the same condition as received, despite the fact that this material is essentially amorphous. This piezocharacteristic was believed due to stresses occurring during processing of the sheet, which established a preferred direction of the material's molecular dipoles. Rolling was thought to be the process involved.

ROLLING PVC AND PVF SHEETS

In the most recent work the scientists treated PVC film of 0.013 to 0.051-mm thickness and polyvinylfluoride (PVF) film of 0.043 to 0.13 mm, from which they cut 5 × 25-mm samples. Electrodes were attached to the lateral faces, for electrical measurements, by evaporation of silver or application of tin foil with rubber cement. The specimens were tested by clamping each in a device that applied an oscillatory mechanical stress along a selected axis and measuring the ac signal generated between the two electrodes.

The scientists first found no piezocharacteristics in PVC that had lost its dipole organization by being heated to 75-80 °C for an hour. The material was then cold-rolled with a mill to thicknesses from 1/3

(*Continued page 259*)

1972 W.D. GEORGE MEMORIAL AWARD

Call for Nominations

THE W. D. GEORGE MEMORIAL AWARD for the best undergraduate student project on instrumentation related to the activities of the Institute of Electrical and Electronics Engineers will be given again in 1972. The student project may be construction and operation of an instrument or a theoretical discussion of the principles and limitations of an instrument.

For the 1972 Award the closing date for nominations is being changed from January 15 to June 15 to coincide with the end of the academic year for the convenience of the nominees. With the new date, students preparing papers to meet academic requirements can prepare copies for submission for the Award more or less simultaneously.

The W. D. George Memorial Award honors William D. George, a distinguished radio scientist who played a major role in advancing the Bureau's standard time and frequency programs at Boulder, Colorado. George died in a 1963 automobile accident in Switzerland while serving as a U.S. delegate to the International Radio Consultative Committee meetings. Contributions by his friends established the award which the IEEE Instrumentation and Measurement Group administers and from which cash awards are made. The award, which is given at an appropriate meeting of the IEEE, consists of a Certificate of Recognition and $100.

Nominations for the 1972 award are to be made by a letter from one of the student's professors in his major field. The letter must give the date of the student's degree, verify the subject matter of the work on which the nomination is based, and be accompanied by evidence of the work in either of two forms:

(1) For nominations based on an unpublished report written by the candidate and giving a definite conclusion, six copies of the report. Normally the work must have been completed in the academic year of the Award, but because of the change in the closing date for the nominations for the 1972 Award, work completed in either the 1970-1971 or the 1971-1972 academic year will be considered.

(2) For nominations based on a paper accepted for publication in an IEEE journal with a publication date between January 1, 1970, and March 1, 1972, six reprint or preprint copies of the candidate's paper on his student project. In the case of multiple authorship only one author will be accepted as a candidate and the nominating letter must specify the degree of his participation.

Each student project may be used to support a nomination for only one year. Nominating letters and supporting evidence for the 1972 Award should be received on or before June 15, 1972, by Joseph F. Keithley, Keithley Instruments, 28775 Aurora Road, Cleveland, OH 44139. Each sponsor will be informed by October 1, 1972, whether his candidate has been selected. Material submitted may be used also to support nominations for other awards, if desired.

A digest of the winning paper will be printed in the Newsletter of the IEEE Professional Group on Instrumentation and Measurement. The complete paper will be considered for publication in the IEEE Student Journal unless other arrangements for publication have been made.

The Selection Committee is headed by Dr. Yardley Beers of the National Bureau of Standards. The other members of the Selection Committee are: Prof. George E. Anner (University of Illinois), Prof. Bruce B. Lusignan (Stanford University), Prof. Thomas Calvert (Carnegie-Mellon University), Prof. illiam J. Barclay (North Carolina State University), and Dr. Donald T. Hess (Clarke-Hess Communication Research Corporation). Submitted material can be returned only if accompanied by a self-addressed and stamped envelope. The Award may be withheld if the Selection Committee believes none of the nominations has sufficient merit.

FORTRAN PROGRAM FOR ARBITRARY-LENGTH ARITHMETIC

RETAINING NUMERICAL ACCURACY DURING ARITHMETIC MANIPULATIONS is one of many subtle problems confronting users of large scale digital computers. Accuracy is often lost in programs for such computations not only from round-off procedures but also from the subtraction of numbers which are very large relative to their difference, with consequent loss in the number of significant figures. A recent examination by the Applied Mathematics Division has indicated that many of the widely used software libraries have been deficient in this respect. A computer program to overcome these difficulties by performing the elementary arithmetic operations with numbers having a fixed but essentially arbitrary number of significant digits was developed by Leonard C. Maximon, a nuclear theorist with the Bureau's Center for Radiation Research. In order to allow the widest possible use, the program was written in FORTRAN, and in such a manner that it was compatible with any of today's large scale digital computers.

The program will be especially useful in obtaining accuracy in research in diffraction problems, where cancellation of nearly equal numbers with consequent loss of significance is inherent. Some examples include x-ray and optical diffraction and the computation of cross sections for the scattering of high energy electrons and high energy protons from nuclei. Beyond these immediate applications in physics the program has important uses in computer technology in general. In particular, it has been used as a tool for the improvement of widely used computer software relating to the basic arithmetic operations and the evaluation of the elementary and special functions. With an arbitrary precision arithmetic program, the function values may be computed with a number of significant figures larger than that given by the fixed word length computer routine to be checked. Of particular interest is the fact that the program, since it simulates in FORTRAN the operations necessary for performing arithmetic—comparison, carrying and shifting—can operate and print out its final answers in any number base.

In addition to these applications in physics and computer technology, the program has engendered research in the field of mathematical analysis in the development of arbitrary precision algorithms for the computation of the elementary and special functions of mathematical physics.

THE PROGRAM

The program consists of a set of subroutines which perform the elementary arithmetic operations—addition, subtraction, multiplication and division—keeping a fixed number of digits throughout the calculation, as well as a number of "peripheral" subroutines which serve as a link to any outside program. The input peripheral subroutines take integer, real or double precision numbers from an outside program and put these in a form suitable for input to the arithmetic subroutines. The output peripheral subroutines take the arbitrary length numbers from the arithmetic subroutines and either convert them to double precision numbers for return to the outside program or simply print them in a form that is convenient to read.

The input to and output from the arithmetic subroutines are the two numbers to be added, subtracted, multiplied or divided, and their resultant sum, difference, product or quotient, respectively, which are in the form of linear arrays containing the digits of the fraction part, the exponent part and the sign of the number in question. The digits could of course be stored successively in the first, second, . . . elements of the array. This would, however, not only be wasteful of computer storage, but, more seriously, result in excessively long computation times: The subroutines for addition, subtraction and multiplication perform these operations in much the same fashion as one does in grade school, the basic operations being addition, subtraction, multiplication, comparison, shifting and carrying. The time required for the addition of two numbers thus increases linearly with the number of digits in the array and the time required for the multiplication of two numbers increases quadratically with the number of digits in the array. The computing time required by these subroutines is thus considerably reduced by storing the digits in groups—the first n digits in the first element of the array, the next n digits in the next element of the array, and so forth. The operations of addition, subtraction and multiplication are then between pairs of blocks of n digits.

The procedure for division of arbitrary length numbers involves the nonlinear recursion

$$x_{n/1} = x_n(2 - Bx_n)$$

which gives the reciprocal of a number, B, using only the opera-

tions of subtraction and multiplication. With this technique, which is quite similar to the commonly used Newton's method for calculating square roots, great accuracy is obtained very rapidly, after only very few steps.

With regard to speed of operation, the basic arithmetic operations, when working with 60 digits for example, take about 1000 times as long as for the same operation in double precision on the same computer. The operations with this program are thus on the order of milliseconds rather than microseconds, as is the case for today's large scale computers.

In summary, a computer is only as useful and as economical as the program running it. The answers given by the computer are of value only if their accuracy can be assured. For many sophisticated calculations this is difficult to insure. The program summarized here offers two important advantages—assured accuracy to as many places as desired and compatibility with all large scale computers.

DISSOCIATION OF GASES BY ELECTRON BOMBARDMENT STUDIED AT JILA

RECENT LABORATORY EXPERIMENTS[1,2] at the Joint Institute for Laboratory Astrophysics (JILA) have shed more light on the processes that break up gas molecules in the upper atmosphere. These dissociation processes are important in determining the composition and temperature of the upper atmosphere, and in initiating some of the chemical reactions that take place there. For example, the lifetimes of atmospheric pollutants at high altitudes are dependent on these dissociation processes, which are caused by impacts with fast electrons.

L. J. Kieffer, a physicist at JILA, which is a cooperative venture between the Bureau and the University of Colorado,says the molecules break apart so quickly it usually isn't possible to observe them with normal spectroscopic techniques. Thus, to learn about the dissociation it is necessary to study the final products.

The dissociation process was studied in this work by measuring the directions and speeds of the ejected fragments after the collision takes place. By comparing the measured data to theoretically calculated values, it was possible to determine the symmetries of the energy states of the original molecule. Knowledge of the symmetry of the molecular state is essential to the prediction of other properties, such as the temperature dependence of the dissociation process.

The instrument used to measure the fragments' speed and direction consists of a vacuum chamber containing the collision chamber, electron gun and ion collector. A small amount of the gas to be studied is admitted to the collision chamber, where the beam of electrons is fired through it at various angles. The fragments produced sometimes acquire a charge, and are called ions. For each angle of the electron beam, some ions manage to pass through a series of apertures and magnetic fields which select ions of a particular momentum. These are then counted electronically to obtain their distribution with respect to direction and momentum.

The experiments demonstrated the importance of molecular recoil in determining the energy and angular distributions of hydrogen and deuterium fragments. The recoil momentum along the beam direction remained constant for all values of electron energy from threshold to 300 eV, a phenomenon not explained satisfactorily by theory. When oxygen was studied, the angular distribution of oxygen ions (O^-) had a strong dependence on electron energy over the range studied (5.75 eV to 8.40 eV). This dependence is consistent with theory, assuming a certain symmetry for the state of the dissociating molecule. Further studies are planned at JILA to more fully explain the process of dissociation and its role in aeronomy.

[1] Van Brunt, R. J. and Kieffer, L. J., Angular distribution of O^- from dissociative electron attachment to O_2, Phys. Rev. A **2**, 1899 (1970).

[2] Van Brunt, R. J. and Kieffer, L. J., Angular distribution of protons and deuterons produced by dissociative ionization of H_2 and D_2 near threshold, Phys. Rev. A **2**, 1293 (1970).

Test vehicle rounds curve in testing effectiveness of siped tires, which have microscopic slots across tread in an effort to increase tire traction. Both siped and unsiped tires were run in this test on a course of the Texas Transportation Institute at Bryan, Texas.

SIPED TIRES NO ADVANTAGE ON WET ROADS

SIPING AUTOMOBILE TIRES DOES NOT IMPROVE THEIR STOPPING ABILITY and resistance to lateral breakaway on wet surfaces. This finding was made at the Office for Vehicle Systems Research* by Arthur Neill, Jr., in work for the Department of Transportation. In tests of siped and unsiped tires on four types of wet road surface there was in general no significant difference between their stopping ability or resistance to lateral breakaway.[1]

SIPING

Siping, or tractionizing, tires consists of making a series of slices across the tread face all the way around the tire without removing any rubber. The process is said by some to improve stopping ability and lateral breakaway on wet surfaces. DOT's National Highway Traffic Safety Administration asked the NBS Office of Vehicle Systems Research to measure and report on the effectiveness of siping.

NBS PERFORMANCE TESTS

NBS tested new and worn tires that were siped by two representative methods against identical unsiped tires. In method A the tire is mounted on the siping machine's hub, it is trued, and eight cuts per inch are made (at 90° to the direction of rotation) across the tire at a depth of 5/32 to 6/32. In method B, seven sipes per inch are cut all the way around the tire at angles of 65° to the direction of rotation and at a depth of 7/32 for new tires and 4/32 for worn ones. For siping by both methods the tires were inflated to 24 psi and the siping was done with the tires loaded to simulate normal tire deflection.

Sixteen identical belted bias tires were used to test siping by method A; half of them were broken in for 100 miles and the other half driven 8000 miles. Four of each group were then siped by method A, yielding one set of each of the following tires: new, new siped, worn unsiped, and worn siped. They were used, one complete set at a time, on an especially instrumented 1968 Chevrolet loaded to 1270 lb per wheel.

The road tests were run on test roadways of the Texas Transportation Institute (an affiliate of Texas Agricultural and Mechanical University) at Bryan, Texas. The stopping distance tests were run on asphalts consisting of bitumen with crushed silicous gravel and bitumen with slag and limestone screenings, as well as on polished concrete made from rounded silicous gravel. Before each run a watering truck coated the road surface with water to a depth of approximately 0.05 inch. For the actual run only diagonally opposite brakes were applied, to maintain lateral stability of the vehicle. The skidding distance traveled from point of lock-up was measured by a "fifth wheel" behind the car, which produced 1 pulse per foot of travel.

Stopping distance tests were carried out on the three courses at speeds of 20, 30, 40, and 50 miles per hour. No truly significant differences were found between siped and unsiped tires, new or old, on these courses and at these speeds. On only one surface, the highly abrasive crushed gravel asphalt, was there a slight improvement in stopping distance for siped tires.

The same tires were used on J-curve courses to determine the highest speed possible without experiencing any lateral breakaway—the greater the speed the better the traction. These courses consisted of asphalts made from rounded silicous gravel and from crushed silicous gravel, shaped in straightaways leading to 288-foot-radius curves. Here, too, there was no substantial difference between the siped and unsiped tires, either new or worn.

Tires siped by method B were tested for stopping distance and lateral breakaway in the same manner (and at 10 miles/hour also), with the same findings. There is no evidence that siping does improve traction on wet surfaces.

[1] Neill, A. H., Jr., Wet traction of tractionized tires, Nat. Bur. Stand. (U.S.) Tech. Note 566 (Feb. 1971), available at a cost of 20 cents from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, as SD Catalog No. C13.46:566.

*The Office was transferred to the Department of Transportation on July 1, 1971.

CRYSTAL FILTER NARROWS, STABILIZES DYE LASER OUTPUT

ELECTRICALLY TUNING A CRYSTAL FILTER located in the cavity of a tuneable dye laser improves the stability and narrows the laser bandwidth. Developed[1] by the NBS Boulder Laboratories and the University of Colorado, this technique offers a powerful new tool for resonance spectroscopy. Even in preliminary diagnostic experiments on sodium vapor, the narrow-emission dye laser produced saturation of atomic resonance transitions. Resonance spectroscopy is expected to be widely used in studies of air pollutants, especially oxides of nitrogen which have overlapping spectra that can be resolved by this new technique. By heterodyning two lasers of different frequencies, it should be possible to extend the range of studies to the infrared where most other pollutants resonate. Geophysical studies may be aided by analyzing the echoes from the natural sodium layer at 95 kilometers, a layer that appears to respond to atmospheric waves.

Birefringent crystals reduce the frequency spread of the emitted light by a factor of 100 or more compared to the spread of an unmodified dye laser. Stability of the 589.6 nm (nanometer) line is temperature-limited to about 0.6 pm (picometer) over a period of 10 minutes; this is a fractional stability of about 1 ppm. The filter can be tuned electrically over a range of 0.4 nm, while the grating-mirror of the laser can be adjusted for larger wavelength increments.

Dr. John Hall, Fellow, and Professor Herbert Walther, Visiting Fellow, at the Joint Institute for Laboratory Astrophysics (JILA) devised this technique. JILA is a research group cosponsored by NBS and the University of Colorado.

The laser under study consists of a flashlamp-pumped rhodamine 6G dye cell in a resonant cavity formed by a 75%-reflecting plane mirror and a 70%-reflecting grating (2160 lines/mm). Pulses are about 0.3 μs long, and the output linewidth is about 0.1 nm when only the grating is used as a frequency-selective element. The center of the output line varies over the same range (0.1 nm) when observed for several minutes without the filter.

The filter consists of 45°, Z-cut potassium dihydrogen phosphate (KDP) crystals, polished on both ends, and coated with gold electrodes on two sides (the Z faces). Antireflection-coated windows are applied to the polished faces with index-matching oil, and the crystals are housed in ovens stabilized near 30 °C. These crystals are also called Lyot filters.[2]

It was found that best results are obtained when a combination of one and five crystals are used, all cut from the same large crystal after the ends are polished and made parallel. Along with the crystals, appropriate polarizers and apertures are placed in the light path in the following order: plane mirror, aperture (1, 2, or 3 mm), dye cell, aperture, quartz plate at Brewster's angle, KDP crystal, Glan prism, five KDP crystals joined by oil, and grating (which serves as the third polarizer). When only one KDP crystal is used, the output power is reduced to 80% of the basic laser power, but high pumping ratios (grater than 1.8 times threshold) produce an extraneous wavelength. Combining six crystals reduces the output to 60%, but narrows the spectrum and eliminates the extra wavelengths.

When the length of the five extra crystals is an integral multiple of the single crystal, all crystals may use the same tuning voltage. A voltage of 10 kV tunes the output over a range of 0.434 nm at the 589 nm wavelength.

The measured temperature coefficient of the crystals is about 0.1 nm/°C. Thus, the wavelength stability of the light (0.5 ppm drift in 10 minutes) corresponds to a temperature drift of only 6 mK, assuming the drift is caused wholly by crystal temperature variations.

[1] Walther, H. and Hall, J. L., Applied Physics Letters, **17**, 6, p. 239 (1970).

[2] Lyot, B., Compt. Rend., **197**, p. 1593 (1933).

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NBS MEASUREMENT SEMINARS 1971-1972 SERIES

Seminars and workshops on the topics listed below have been announced for the 1971-1972 series of NBS Measurement Seminars. These are scheduled to be given either at the NBS laboratories in Gaithersburg, Md., indicated by (G), or in Boulder, Colo., indicated by (B). The announced topics are as follows:

Radiation Quantities (G) . . May 9-12, 1972

Laser Power and Energy Measurements (B) . . March 9-10, 1972

The seminars and workshops are one of several NBS activities that provide advice and assistance on measurement and calibration problems to the growing number of standards laboratories in tracing to NBS standards the accuracies of measurement needed for research work, factory production, or field evaluation. Participation is open to a limited number of persons from measurement and standards laboratories who meet appropriate prerequisites relating to education, work experience, and current professional activity.

Each seminar lasts from two to four days and its meetings are devoted to lectures, group discussions, and laboratory demonstrations. A course may be cancelled if registration is insufficient. However, in the past, requests for enrollment have nearly always exceeded the numbers that could be accommodated. Laboratory directors who wish to have members of their staff attend either of these courses are therefore urged to send, as soon as possible, a letter of application to the individual named in the course descriptions below. Letters should include:

*Applicant's name and address
*Citizenship
*Company or agency affiliation
*Title of position in company or agency
*College level training
*Supervisory or laboratory experience related to precision measurement

Applications should also be accompanied by a check, billing authorization, or purchase order for the stated fee, made payable to the National Bureau of Standards. Reprints of the material to be reviewed prior to the seminar will be mailed upon acceptance of this application.

Acceptance of qualified applicants, on the basis of first come first served, other things being equal, will be made by letter not later than four weeks prior to the scheduled date of the course. Detailed information on schedules and housing will be available at that time. Those accepted will be expected to study the assigned reading material before coming to the course and should be prepared to discuss their own experiences with related problems.

Radiation Quantities (G)

Brief Description: This 4-day seminar will cover the measurement of four categories of radiation: x-rays, electrons, neutrons, and radioactivity. For each type of radiation, the principles of measurement and the important instruments and techniques will be discussed. Visits to NBS radiation and measurement laboratories will be included. For x-rays, emphasis will be placed on exposure and absorbed dose measurements. For electrons, the topics to be considered are dosimetry, measurement of beam parameters, and beam handling and positioning techniques. For neutrons, calibration of sources, thermal and fast neutron flux density, and integral measurements of neutron fluence and spectra will be considered. In the area of radioactivity, topics such as counting techniques, microcalorimetry, and calibration of standard samples will be covered.

Prerequisites: Applicants must have undergraduate college-level training in physics, chemistry, or engineering, and must currently be involved in radiation measurement, either directly or in a supervisory capacity. Preparation for the seminar should include a review of NBS Handbook 85, *Physical Aspects of Irradiation*, NBS Handbook 80, *A Manual of Radioactivity Procedures*, and ICRU Report 11, *Radiation Quantities and Units*.

Arrangements: Attendance will be limited to 30 people. Fee: $200. Tentative dates: May 9-12, 1972. Apply to E. H. Eisenhower, NBS Center for Radiation Research, Washington, D.C. 20234.

Laser Power and Energy Measurements (B)

Brief Description: The 2-day seminar will discuss the principles and techniques used by NBS to measure the power and energy output of lasers. Measurements cover the wavelength range from 488.0 nm to 10.6 μm, cw power up to 200 W, and pulse energy up to 100 J. Measurement of average power and peak power of high rep-rate lasers

will also be discussed. Topics discussed will include calorimeters, detectors of various types, beam sampling methods, pulse shape measurements, and error analysis.

Prerequisites: Applicants must have college-level training in engineering or physics, or equivalent experience, and should be currently concerned with measurements of the properties of laser beams.

Arrangements: Attendance will be limited to approximately 40. If fewer than 20 applications are received by the closing date, the course will be cancelled and fees refunded. Fee: $100 (includes light refreshments to be served during coffee-breaks). Dates: March 9-10, 1972. Apply to: Administrative Officer, NBS Quantum Electronics Division, Boulder, Colorado 80302 (Tel: (303) 447-3671) by February 15, 1972.

INCRA Funds Copper Study

THE BUREAU HAS BEEN GIVEN $30,000 BY THE INTERNATIONAL COPPER RESEARCH ASSOCIATION (INCRA) for a one-year preliminary study of the properties of high-purity copper in high magnetic fields. In this study the Cryogenics Division (Institute for Basic Standards, NBS) in Boulder, Colorado, under the direction of Dr. F. R. Fickett, will investigate the electrical resistance at low temperatures of vacuum-annealed and oxygen-annealed wires of very high purity. The Bureau has performed similar studies on ultra-pure aluminum.

The information is sought because of proposed applications of high-purity metals in such fields as magnetic suspensions for trains, powerful magnets and motors, and electric power transmission. Pure normal metals, such as copper and aluminum, may well rival superconductors for some of these uses, and even superconductors must be stabilized by embedding them in a low-resistance normal-state metal, such as copper.

MAGNETORESISTANCE

A magnetic field increases the resistivity of most conducting materials; the increase is negligible, however, at room temperature. At cryogenic temperatures, say from 4 to 20 K, the resistivity can be as much as ten times greater because of the magnetic field, and this magnetoresistance effect is greatest in high-purity metals. Naturally, it is not profitable to purify the metal to obtain low resistivities only to lose this advantage in a strong magnetic field, especially since achieving that field is usually the purpose of building the cryoelectric apparatus in the first place. The questions to be answered in the study are, then:

1. Is it possible to produce polycrystalline copper wires with the same low resistivity exhibited by single-crystal samples?
2. How does the low-temperature resistance of these wires vary with purity and magnetic field?

Copper could be a viable alternative to aluminum if its resistivity decreases more rapidly with descreasing temperature than it increases with magnetic field strength.

RESIDUAL RESISTANCE RATIO

The best measure of extreme purity for metals is the residual resistance ratio (RRR), defined as the ratio of resistance of a sample at 273 K to its resistance at 4 K

$$\left[\text{RRR} = \frac{\text{R(273 K)}}{\text{R(4 K)}}\right].$$

It is a better measure for electrical purposes than analysis for chemical impurities, because different impurities will cause different resistivity changes at the same concentrations. The RRR is also much more sensitive, indicating some impurities at levels far below those detectable by other techniques. Ordinary copper wire has a RRR of about 50, but the Cryogenics Division has produced, through an oxygen annealing process, single-crystal copper boules with a RRR of 50,000. It is hoped that a RRR of about 30,000 can be maintained when the copper is formed into wires, but this remains to be shown by the study.

THE PROPOSED STUDY

After the RRR of the annealed wires has been measured in zero magnetic field, it will be measured again with the field normal to the current and parallel to it, at field intensities up to 100 kilogauss. Temperatures will range from 4 to 20 K at least, and perhaps from 2 to 30 K if time permits and results look promising. The results of these tests will be interpreted in terms of copper's potential for large-scale applications, as well as the implications for the basic physics of the metal. If the results are promising, further investigations of the mechanical properties of high-purity copper will be proposed. It is believed that the purification-annealing process enhances the mechanical strength of copper, making it superior to aluminum in that respect. The mechanism by which oxygen-annealing improves the RRR also needs more study to be better understood.

DEFECTS IN WIRE BONDS

A Cause of Semiconductor Device Failure

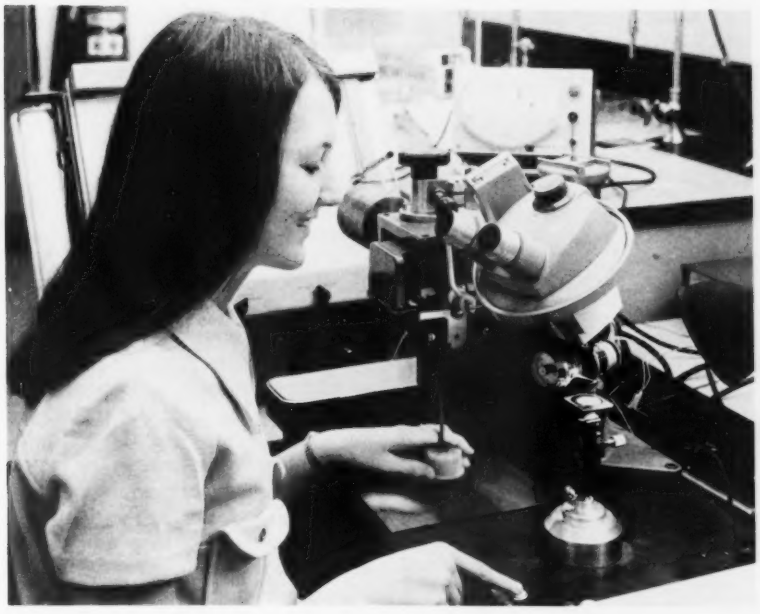
THE BUREAU HAS ANNOUNCED PRELIMINARY RESULTS in its two-year search for causes of and methods for minimizing defective bonds of wire leads to metallized semiconductor surfaces. The findings of a team of semiconductor scientists of the Electronic Technology Division have illuminated some of the causes of failures in microelectronic wire bonds.[1] The methods developed by the scientists for calibrating the ultrasonic wire bonders on industrial production lines should result in semiconductor microelectronic devices—transistors, diodes, and the newer integrated circuits—having fewer failures than present devices.

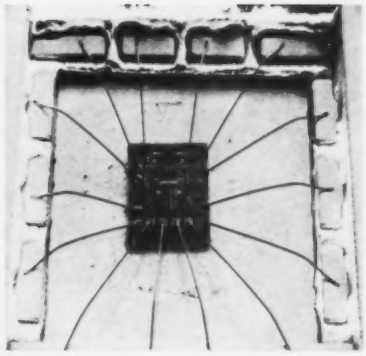
Herbert Kessler positions a magnetic pickup beside the end of an ultrasonic tool used to bond aluminum wire leads to metallized pads on semiconductor wafers. He will then use an oscilloscopic display of the pickup signal to adjust the transducer driver for the desired frequency and amplitude at the tool tip.

FABRICATING SEMICONDUCTOR DEVICES

The active components of a semiconductor microelectronic device are very small (about 0.01 to 0.1 inch), so that connecting them to the package leads presents a problem and is often the source of device failures. Connection is from the metallized areas on the semiconductor chip, called pads, to the package leads by means of 0.001-inch aluminum or gold wire, often attached by ultrasonic welding. A delicate and highly specialized bonding machine is used to position the end of the wire in relation to the pad and to press the tip of a bonding tool against it. When the bonding tool transducer is energized by ultrasonic power at a frequency of about 60 kHz, the tool tip vibrates with a displacement of 50-70 microinches. It is pressed against the wire to break up the metal surface oxide and weld the wire to the pad. The other end of the wire is typically attached to a header pin on the package by the same means.

Failure of these welded contacts by lift-off from the pad or breakage in the wire is a major cause of early device failure. Such difficulties led Government agencies concerned with device reliability—several De-





Micrograph of a microelectronic device showing the wires that connect the semiconductor circuit chip, in the center, to the package leads. The flattened areas at the ends of each wire are the ultrasonically formed bonds.

Cynthia Main operates a bond-pulling machine that measures the strength with which the tiny wire leads are bonded to pads on semiconductor devices.

partment of Defense agencies and the National Aeronautics and Space Administration—to sponsor the Bureau's research into the causes of and cures for this problem.

NBS RESEARCH

The first step in the Institute's wire bond evaluation program was to study the open and classified literature in order to assemble a bibliography of information relevant to the field and to write a critical review of the present state of that field. This task, undertaken by Harry Schafft, familiarized the Institute staff with the techniques and methods used in industry.[2]

A destructive pull test has long been used to determine if leads adhere well enough to the pads to withstand stipulated tension levels. Somewhat inexact in its usual form, the pull test is being analyzed at the Institute, using a statistical approach to determine its usefulness in specifying bond quality. This test is widely used in industry for quality control purposes, but because it is destructive it can only be used on a sample basis.

Knowledge of how the lead-to-pad weld is formed has been greatly advanced by removing the bond from the pad and microscopically examining the adhesion patterns on the pad. Photomicrographs of the pads made with the Bureau's scanning electron microscope by Kathryn O. Leedy[3] show that an ultrasonic bond is formed under the vibrating tool in this sequence: the 0.001-inch aluminum wire is flattened, the area under the wire is polished as a result of the wire's movement against it, and bonding begins at random localized points (not necessarily the same for successive specimens) and then appears at additional areas typically covering the bond heel and toe area. Then the weld spreads around the sides of the wire; the center area frequently remains unbonded, even for some very strong bonds.

Early in the project, George G. Harman and Herbert K. Kessler experimented with different methods of measuring motion of the bonding tool tip. The conventional method, which was used in setting the power supply frequency and power, was to observe the resonant dip of the electrical current used to drive the ultrasonic electromechanical transducer. In many bonders, however, this dip does not correspond with the maximum ultrasonic motion of the bonding tool. Methods developed at NBS have involved the measurement of the ultrasonic motion at the bonding tool tip using a capacitor microphone or a magnetic pickup.

Use of the capacitor microphone made it possible to monitor the tool movement with the aid of an oscilloscope and to determine the effects of changes in transducer power, frequency, mounting method, and in tool length and position. More recently a magnetic sensor has been used in place of the microphone, and sensors have been calibrated against tool movement measured by a laser interferometer.

The ultrasonic displacement-

Kathryn Leedy positions a semiconductor wafer under a bonding tool. The tool will be lowered to press the aluminum wire against a metallized pad on the wafer and ultrasonic energy will then be applied to form a weld between wire and pad.

measuring techniques disclosed a number of uncontrolled factors in ultrasonic bonding. One example is the consequence of changing tool extension below the transducer horn. The tool is mounted in a hole drilled through the horn and is clamped by a setscrew. There are critical regions of tool extension that produce undesired resonance of the tool alone. Plotting the vibration amplitude at points along the length of the tool discloses a characteristic system of standing waves, with a node midway between the peaks at the tip and at the horn. The ultrasonic vibration amplitude at the tool tip and the shape of the standing wave pattern can be altered unpredictably by a slight change in position of the tool in the horn.

One source of this unexpected variability was found when the tool was removed and replaced in the same apparent position; the standing wave pattern resulting was considerably changed from the earlier one. This difference was found to be due to variations in the seating of the tool in its hole when clamped by the setscrew.

The effects of uncertainty about the horn-tool interface can be avoided by using the output of either the magnetic sensor or the capacitor microphone to adjust the ultrasonic power generator for the desired motion at the tool tip. The magnetic detector is relatively easy to use by an inexperienced operator, making it particularly useful in re-establishing the desired tool tip amplitude after any change.

OTHER CAUSES OF POOR BONDS

Other uncontrolled factors which have been observed to have a significant effect on the bonding process include unwanted vibration in the system induced by the machine itself, the building, and the operator's hand. Such vibrations can cause movement of the work stage relative to the tool tip which, if it occurs during the actual bonding period, may result in a lift-off or low pull-strength bond. Special brackets increasing the rigidity of some bonding machines help reduce unwanted vibration.

It was found in a study of the temperature characteristics of the ultrasonic transducer system, that the multiple high-intensity lamps used to illuminate the work area on some machines can cause detuning as the unit warms up. To obtain reproducible bonds, heat-absorbing filters should be used in front of the lamps or the transducer should be preheated by turning on the lights for several hours prior to bonding. The results of these studies and possible cures for some of the factors found to be detrimental to the bonding process have been shown to increase the yield of devices when applied to industrial use.

[1] Harman, G. G., and Kessler, H. K., Application of Capacitor Microphones and Magnetic Pickups to the Tuning and Trouble Shooting of Microelectronic Ultrasonic Bonding Equipment, Nat. Bur. Stand. (U.S.) Tech. Note **573** (April 1971), Superintendent of Documents Catalog No. C13.46:473.

[2] The bibliography and the review will be published as NBS Technical Notes.

[3] In preparation, to be published as an NBS Technical Note.

A continuing account of the Institute's work on wire bond evaluation, as well as of its entire research in semiconductor technology, can be found in the series of quarterly reports edited by W. Murray Bullis and published as NBS Tech. Notes entitled **Methods of Measurement for Semiconductor Materials, Process Control, and Devices**. They are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. To date the issues, periods covered, prices, and Superintendent of Documents Catalog Numbers are:

TN 472, July 1 to Sept. 30, 1968, 50 cents, C13.46:472
TN 475, Oct. 1 to Dec. 31, 1968, 45 cents, C13.46:475
TN 488, Jan. 1 to Mar. 31, 1969, 50 cents, C13.46:488
TN 495, April 1 to June 30, 1969, 50 cents, C13.46:495
TN 520, July 1 to Sept. 30, 1969, 65 cents, C13.46:520
TN 527, Oct. 1 to Dec. 31, 1969, 60 cents, C13.46:527
TN 555, Jan. 1 to Mar. 31, 1970, 65 cents, C13.46:555
TN 560, Apr. 1 to June 30, 1970, 60 cents, C13.46:560
TN 571, July 1 to Sept. 30, 1970, 60 cents, C13.46:571

Simpler Microwave Power Calibration

THE MEASUREMENT OF MICROWAVE POWER METERS AND SYSTEMS is complicated by mismatch errors. These errors (or corrections) may be evaluated by measuring complex reflection coefficients; this measurement is limited, in part, by connector imperfections. More often the correction is ignored, and thus becomes an error.

"Power equation" methods simplify the determination of mismatch which in turn yields a higher accuracy. These methods make reflection-coefficient measurements unnecessary, relax the precision-connector requirements, and furnish a new tool for connector evaluation.

Microwave power calibrations ultimately are referred to NBS primary stnadards through a chain, or hierarchy, of measurements. Each step in the chain, from NBS down, degrades the accuracy. This degradation is much larger for microwave power measurements than for dc voltage, low-frequency current, or similar parameters. Although the practical problems in intercomparing bolometer mounts and directional coupler-bolometer mount combinations are substantial, these items are the primary elements used to transfer a calibration from one level in the hierarchy to another.

The problem centers around the difficulty of making good mismatch corrections. Until recently, no simple and direct method existed for measuring and applying this correction. The new method,[1] developed by G. F. Engen of the NBS Boulder Laboratories, involves the techniques of his recently developed "power equations"[2] to evaluate this correction more easily and accurately, thereby improving each step in the hierarchy.

The new technique was evaluated in the NBS laboratories in a simulated calibration hierarchy of 6 steps. Comparing the final calibration to the original yields an indication of the accumulated error. Old and used connectors and new improved versions were employed in the experiment carried out at 9 GHz. The measurements revealed that the older type-N connector contributed one-half the error of two different "improved" versions, regardless of standing wave ratio. In fact, the older type N equaled the performance of the recently developed GPC-7. Only conventional waveguide flange connectors gave better results; these however, are suited only for waveguide, not coaxial cable. The experiments indicated the new method to be very insensitive to connector imperfections and confirmed theoretical predictions of connector behavior. (Note that only the repeatability of the power dissipation at the connector interface was measured, not impedance.) For a 6-step hierarchy, type-N accumulated error measured about 0.3 percent, while waveguide flange error was about 0.15 percent.

This measurement procedure is simple enough to use at the field level, where component tolerances and projected benefits are largest. Thus, employing this technique and proper quality control at each level enables a calibration to propagate to the lowest level while accumulating less than 0.5 percent error.

[1] Engen, G. F., An improved method for microwave power calibration, with application to the evaluation of connectors, presented at the 1970 Fall Meeting of URSI, September 15-17, Ohio State Univ., Columbus, Ohio. Also scheduled for publication in an early issue of the NBS Journal of Research, Section C.

[2] Engen, G. F., Power equations: A new concept in the description and evaluation of microwave systems, IEEE Trans. of Instr. and Meas., IM-20, No. 1, Feb. 1971.

New ASTM Section on Microelectronic Bonding

THE BUREAU WAS HOST FOR THE JUNE 7, 1971, ORGANIZATIONAL MEETING of a new Section of Committee F-1 on Electronics of the American Society for Testing and Materials (ASTM). The Section was formed to develop standard test methods for microelectronic bonding. More than 40 representatives of producers and users of microelectronic devices attended the meeting, chaired by Kathryn Leedy of the NBS Electronic Technology Division.

The new Section is part of Subcommittee 7 on Hybrid Microelectronics, which is concerned with tests for ceramic substrates, thin film and thick film circuits, and hermeticity of device packages. Areas chosen for initial investigation by the Section include the destructive pull test, deformation of wire bonds, visual inspection of wire bonds, temperature cycling, specifications for wire and bonding tools, and tests for metallization and beam leads. In addition, a terms glossary is being developed for this field.

The Committee operates by developing voluntary standards for materials and processes; 125 such documents appear in Part 8 of the Annual Book of ASTM Standards and the Committee is actively working on 80 new methods and associated documents. These are being developed with the widest possible participation from interested parties. Persons interested in working with the new Section are invited to contact its Chairman, Kathryn Leedy, B328 Technology Building, National Bureau of Standards, Washington, D.C. 20234.

CONFERENCE & PUBLICATION *Briefs*

13th SCINTILLATION AND SEMICONDUCTOR COUNTER SYMPOSIUM

Radiation detectors which play an important part in the advancement of such fields as medicine, interplanetary space science, and environmental science are the subjects of the 13th Scintillation and Semiconductor Counter Symposium to be held March 1-3, 1972, at the Shoreham Hotel in Washington, D.C. Sponsors for this biennial event are the Nuclear Science Group of the Institute of Electrical and Electronics Engineers, the Atomic Energy Commission, and NBS.

Attendees will be concerned with new improvements and new applications for radiation detectors as well as with current problems. The six single sessions of invited and contributed papers will cover the topics: scintillation and fluorescence phenomena; photomultipliers; single optical photon detection; semiconductor detectors; track imaging, spark and proportional counters; x-ray detection and spectroscopy; other detectors of ionizing radiation; spectrometry; biomedical detectors and applications; detector arrays and data handling; signal conditioning circuits; low noise preamplifiers; space applications; and scintillation and semiconductor detector applications.

Dr. Gordon MacDonald of the President's Council on Environmental Quality will be the speaker for the banquet planned for the first evening of the Symposium, March 1. Also associated with the Symposium will be an exhibit of the latest equipment in the field.

JOINT MEASUREMENT CONFERENCE

A Joint Measurement Conference, the first in a potential series, will be held June 21-23, 1972, at Boulder, Colorado. The keynote of the Conference—THE ROLE AND VALUE OF MEASUREMENT—is also the theme of the opening address, to be presented by Lewis M. Branscomb, Director of the National Bureau of Standards.

The joint aspects of this Conference are indicated by the list of sponsors:

- American Society for Quality Control—Electronics Division/Metrology Technical Committee
- Institute for Electrical and Electronics Engineers-Group on Instrumentation and Measurement
- Instrument Society of America-Metrology Division
- National Bureau of Standards
- National Conference of Standards Laboratories
- Precision Measurements Association

The purpose of the meeting is to promote the interdisciplinary exchange of technical and managerial measurement concepts. The underlying theme is that, ideally, technical personnel should utilize the measurement science concepts in all phases of product evolution—research, design, development, manufacturing, maintenance, and quality control. The techniques of a systems approach to accurate, meaningful measurements will be emphasized as a powerful tool for both management and technical personnel. The sessions will stress that many, if not all, measurement disciplines are required in the solution of software/hardware oriented measurement problems.

The Conference, to be held at the NBS Boulder Laboratories, is organized into 6 consecutive half-day sessions. The general topic of the first day, The Why of Measurement, is explored in sessions on The Measurement Effort as a Resource for Management, and as a Technical Resource. The How of Measurement is covered in Sessions on Physical Processes in Sensors/Transducers/Detectors, and Interdisciplinary Solutions of Problems, and the Where of Measurement is discussed in sessions on Systems Metrology and Measurement-Oriented Engineers from our Campuses.

Attendees of the Joint Measurement Conference have the opportunity to take in a "conference doubleheader," as the Conference on Precision Electromagnetic Measurements meets in Boulder June 26-29.

For further information, contact:

George Goulette
Director, Bureau of Conferences and Institutes
University of Colorado
130 Academy Building
970 Aurora Avenue
Boulder, Colorado 80302
Phone: (303) 443-2211 Ext. 6485

11 WAYS

A brochure—*11 Ways to Reduce Energy Consumption and Increase Comfort in Household Cooling*—has been prepared by NBS in cooperation with the President's Office of Consumer Affairs. Detailed are 11

steps that will keep your dwelling cooler, consume less energy, lower your cooling bill, and reduce environmental pollution.

As NBS Director Lewis M. Branscomb and Virginia Knauer, Director of the Office of Consumer Affairs, point out in their forword to the brochure, "The nation today faces increasing demands for fuel and power...care in the use of energy can benefit the household consumer through economic savings, increased comfort, and reduction in environmental pollution...many of the measures suggested for air conditioning serve also to reduce energy consumption through the heating season...many of these suggestions benefit families who do not use air conditioning."

11 Ways is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, for 35 cents. Use catalog number C13.2:EN2 when ordering.

A companion brochure, 7 Ways to Reduce Fuel Consumption in Household Heating, released last year, is now available from GPO. The price is 25 cents; use catalog number C13.2:F95 when ordering.

Computer Program Supplies Figures For Revenue Sharing Bill

THE CENTER FOR COMPUTER SCIENCES AND TECHNOLOGY has devised and run a computer program that calculates amounts of Federal funds to be shared with states, counties, municipalities, and townships according to the terms of a bill before Congress. The program was written by John M. Smith, of the Center's Computer Services Division, at the request of the Department of the Treasury.[1] The computer printout, which gives the amounts to be shared with each of over 10,000 political subdivisions, was used with bills introduced in the Senate and the House of Representatives for President Richard Nixon; they are now in committees of the two bodies.

President Nixon in his February 4 message to Congress recognized the increasing difficulty experienced by the states and cities in funding vital programs. He attributed this to the way in which our tax system has developed, with the Federal Government taxing personal income since 1913 while the states and local governments derive most of their revenues from property and sales taxes. Income tax revenues, he noted, are quick to reflect economic growth, while revenues from properties and sales taxes are slow to respond to economic expansion and may lag 50% behind growth required in State and local expenditures.

The President offered as a solution sharing Federal revenue with the country's political subdivisions, without Federal control of the money's use. He proposed in a general revenue sharing program that an amount equal to 1.3% of the Nation's taxable personal income—about $5 billion the first year—be divided among the states (and the District of Columbia) in proportion to their population under a formula rewarding each for its own revenue-raising efforts. A state not having a plan for distributing its shared income to its political subdivisions would receive only about half for itself, the rest being apportioned among its counties, cities, and townships in a manner similar to the distribution among the states.

Before introduction of the bills the Department of the Treasury asked NBS to set up a computer program for calculating the allotment due each state, its counties, and its other subdivisions of more than 2,500 population. Dr. Smith wrote this computer program in the FORTRAN V computer language and ran it on the Bureau's 1108 computer, using as inputs the total amount to be distributed and population and tax revenue figures obtained from the Bureau of the Census.

The computer printout lists for each state the gross amount allotted to it and the "pass-through" percentage for distribution to its subdivisions. The next listing gives the totals allotted to cities and townships and their total revenue reported. This is followed by a similar listing for the counties.

The computer printout supplied by NBS was published by the Treasury Department's Office of the Special Assistant for Public Affairs to show the legislators and would-be recipients the distribution for the program's first year, if the bill is passed. The computer program can be used in subsequent years with updated figures from the Census Bureau to compute revenue shares for each following year.

[1] **General Revenue Sharing,** published by the Department of the Treasury Office of the Special Assistant for Public Affairs (Feb. 1971).

NSRDS NEWS

The NSRDS was established to make critically evaluated data in the physical sciences available to science and technology on a national basis. The NSRDS is administered and coordinated by the NBS Office of Standard Reference Data.

SIXTH ANNUAL MEETING OF CODATA

In 1966, the International Council of Scientific Unions sponsored the organization of a Committee on Data for Science and Technology (CODATA) to promote and coordinate data-compilation activities on a world-wide basis and to stimulate the interest and cooperation of appropriate funding agencies.* Nations participating in CODATA are: Canada, Federal Republic of Germany, France, German Democratic Republic, Israel, Italy, Japan, the Netherlands, Poland, Sweden, United Kingdom, United States, and U.S.S.R. The central office is located in Frankfurt, Germany, with Dr. C. D. E. Schafer as Executive Director.

The Sixth Annual Meeting of CODATA was held at the National Academy of Sciences, Washington, D.C., July 19-20, 1971. A one-day symposium and panel discussion on Principles and Practices of Data Evaluation, organized by the U.S. Numerical Data Advisory Board, was held on July 21 at the National Bureau of Standards. The symposium included the following presentations: "Some Pitfalls and Pleasures of Data Analysis," by Dr. J. Ross MacDonald, Texas Instruments, Inc.; "Systematic Uncertainties (Atomic Collisions)," by Gordon H. Dunn, Joint Institute for Laboratory Astrophysics; "An Experimentalist's View of Experimental Uncertainties," by Professor D. N. Langenberg, University of Pennsylvania; and "Some Remarks on the Statistical Treatment of Random and Systematic Errors," by D. R. Gardiner, Oak Ridge National Laboratory. A panel discussion on "Problems Connected with the Presentation of Data in the Primary Literature," was also held. Dr. D. R. Lide, Jr., Chief, Office of Standard Reference Data, was moderator. Journal editors on the panel were Dr. S. Pasternak, *Physical Review;* Professor E. F. Westrum, Jr., *Journal of Chemical Thermodynamics;* and Professor N. Hackerman, *Journal of the Electrochemical Society.* Data center operators on the panel included Dr. L. J. Kieffer, JILA Information Analysis Center; Professor Y. S. Touloukian, Thermophysical Properties Research Center, Purdue University; Dr. D. Garvin, Chemical Kinetics Information Center, NBS; and Professor B. J. Zwolinski, Thermodynamics Research Center, Texas A & M University. Some of the problems discussed were economical aspects of presenting large quantities of data and the presentation of research results in sufficient experimental detail to allow meaningful evaluation.

The Third Biennial International CODATA Conference, with the theme "Generation, Collection, Evaluation and Dissemination of Numerical Data for Science and Technology," is scheduled to be held in France during the last week in June 1972. The Conference Chairman will be Professor B. Vodar, President of CODATA and Chairman of the French National Data Committee. The exact date, location, and program details of this Third International CODATA Conference will be announced later.

CURRENT NUMERICAL DATA ADVISORY BOARD MEMBERSHIP

The Numerical Data Advisory Board of the National Academy of Sciences, National Academy of Engineering, and National Research Council, has the following primary functions: 1) advisory services to the Office of Standard Reference Data through panels of specialists convened at the request of NBS; 2) encouragement of the national efforts in data compilation; and 3) liaison between the scientific community and CODATA–ICSU

through a U.S. National Committee for CODATA. In addition, the Numerical Data Advisory Board promotes uniform practices in regard to internationally accepted symbols, units, constants, and nomenclature. Current membership in the Board are: Dr. J. Ross MacDonald, Chairman, Texas Instruments, Inc.; Dr. H. I. Fusfeld, Kennecott Copper Corporation; Dr. H. C. Gatos, Massachusetts Institute of Technology; Dr. Robert M. Hayes, University of California, Los Angeles; Dr. G. G. Johnson, Jr., Pennsylvania State University; Professor William Klemperer, Harvard University; Dr. H. W. Koch, American Institute of Physics; John W. Murdock, Battelle Memorial Institute; Dr. R. W. Schmitt, General Electric Co.; and W. O. Taff, Esso Research. H. van Olphen serves as Executive Secretary of the Numerical Data Advisory Board.

U.S. NATIONAL COMMITTEE FOR CODATA

Members of the current U.S. National Committee for CODATA are: Professor Robert B. Brode, Chairman, University of California; Dr. Lewis M. Branscomb, U.S. National Representative to CODATA, National Bureau of Standards; Dr. W. S. Brown, Bell Telephone Laboratories; Dr. Ned A. Ostenso, Office of Naval Research; Professor Earnest F. Gloyna, University of Texas; Dr. J. Ross MacDonald, Texas Instruments, Inc.; Dr. Michael E. Senko, IBM Research Laboratory; Professor Edgar F. Westrum, Jr., University of Michigan; Professor Ronald Geballe, University of Washington; Dr. E. U. Brady, ex officio, National Bureau of Standards; Professor Harrison Brown, ex officio, National Academy of Sciences; Dr. Bruce S. Old, ex officio, National Academy of Engineering; Dr. Philip L. Altman, ex officio, Federation of American Societies for Experimental Biology; Professor J. T. Edsall, ex officio, Harvard University; Professor Frederick D. Rossini, ex officio, Rice University; and Dr. Guy Waddington, ex officio.

THERMODYNAMICS RESEARCH CENTER

The Thermodynamics Research Center (TRC) is located in the Research Center of Texas A & M University, College Station, Texas, and is directed by Bruno J. Zwolinski. The activities of TRC encompass data evaluation and compilation as well as theoretical and experimental research. The data compilation projects include not only thermodynamic and other physicochemical properties, but also infrared, ultraviolet, Raman, mass and nuclear magnetic resonance spectral data. This work is carried on by a staff of about 14 professional workers, plus editorial and office personnel. Research carried out by staff members and graduate students is closely coordinated with the compilation efforts. In addition, literature searches are routinely carried out. Three distinct projects operate within TRC: the American Petroleum Institute Research Project 44, the Thermodynamics Research Center Data Project, and critical evaluation of data supported by the Office of Standard Reference Data. Under the OSRD activity a critical compilation entitled "The Physical and Thermodynamic Properties of Pure Aliphatic Alcohols," has been prepared and will be published in the near future. The API project and projects within the Thermodynamics Research Center issue sets of looseleaf data sheets on various categories of data. The sets, supplements to them, and prices are listed in the table below.

*See NSRDS News, September 1969.

Categories of Data Sheets	American Petroleum Institute Research Project 44 — *Selected Values of Properties of Hydrocarbons and Related Compounds*			Thermodynamics Research Center Data Project — *Selected Values of Properties of Chemical Compounds*		
	Data Sheets Available	Price, Initial Sets	Price, 1971 Supplements	Data Sheets Available	Price, Initial Sets	Price, 1971 Supplements
A. Tables of selected values of **PHYSICAL AND THERMODYNAMIC PROPERTIES,** including status sheets	2563	$ 826.55	$ 72.00	1079	$ 357.50	$ 48.00
B. **SELECTED INFRARED SPECTRAL DATA,** including indices	3079	981.30	30.00	665	222.25	60.00
C. **SELECTED ULTRAVIOLET SPECTRAL DATA,** including indices	1154	369.05	16.00	166	58.75	16.00
D. **SELECTED RAMAN SPECTRAL DATA,** including indices	501	173.15	16.00	81	33.25	16.00
E. **SELECTED MASS SPECTRAL DATA,** including indices	2681	848.00	52.00	330	114.90	38.00
F. **SELECTED NUCLEAR MAGNETIC RESONANCE SPECTRAL DATA,** including indices	966	312.65	48.00	929	301.55	30.00
Totals	10944	$ 3510.70	$ 234.00	3250	$ 1088.30	$ 208.00

OPTICAL RADIATION NEWS

NBS HAS EXTENSIVELY REORGANIZED ITS WORK IN RADIOMETRY, PYROMETRY, PHOTOMETRY, AND SPECTROPHOTOMETRY. These areas are now combined in the Optical Radiation Section of the Heat Division, and are under the leadership of Dr. Henry Kostkowski. This reorganization will permit the Bureau to coordinate its efforts in these closely related fields and to utilize its expertise more efficiently. Plans are being made to place new major emphasis both on laboratory research and development and on the interaction between NBS and the technical community. This new Technical News Bulletin column, Optical Radiation News, is one of the ways of increasing this interaction.

GENERAL GOALS

Recent communication between NBS on the one hand and industry, other government agencies, and universities on the other has led the Bureau to establish and work toward the following nationwide goals:

(1) The capability to perform radiometric and photometric measurements to an accuracy of 5% should be commonplace.

(2) The standards and procedures required to perform 1% measurements should be well documented and readily available.

(3) The NBS research program should be responsive to the need for radiometric and photometric measurements of better than 1% where necessary.

PROGRAM

To meet these goals a three point program is being developed at NBS with the combined resources of the new Optical Radiation Section:

(1) Greatest emphasis is being placed on research geared to the development of a number of new basic standards, the designation of their uncertainties, and the specification of the techniques for their use. The key element in this work is a quantitative investigation and improvement of the accuracy of all the NBS radiometric and photometric standards:

(a) spectral radiance, for which standards already exist at the 1% level, (b) spectral irradiance, (c) irradiance, (d) luminous intensity, and (e) luminous flux.

(2) The second major element in this program is a more widespread and accurate dissemination of these standards and of the techniques for using them. Increased coordination with the secondary standards laboratories in government and industry will be required. Published interlaboratory comparisons will be used to characterize the capability of the secondary laboratories and to demonstrate that this capability is being maintained. Those standards or calibrations not available from the secondary laboratories, those possessing state-of-the-art accuracy, or those associated with widespread problems will be available directly from NBS.

(3) Fundamental to a permanent, long term improvement in the areas of radiometry and photometry is the need for increased emphasis on radiometric and photometric training and information dissemination in this country. Present plans in NBS include this column and tutorial monographs as well as the more traditional technical papers. If necessary, NBS will also become more heavily involved in educational activities in this area.

BACKGROUND

Photometry, the measurement of electromagnetic radiation weighted

with the response of the human eye, is the oldest branch of the measurement of photon flux and has been a focus of international activity for the past 70 years, in fact since the foundation of NBS. It was built first around flame sources, which were replaced by incandescent lamps. Because incandescent lamps can be made with relatively similar characteristics, the comparison of two lamps could formerly be achieved with an acceptable amount of ambiguity. Radiometry, on the other hand, is the newer but more general measurement of photon flux; conceptually it includes photometry as a subdivision.

Several factors now require a more sophisticated understanding of both radiometric and photometric measurements than has previously been achieved. The rapid march of electro-optics and space optics places tighter requirements on measurements in order to support and document the continued improvement of these mercurial fields. In addition, a far greater variety of sources must now be measured to tolerances that have previously been approached only with tungsten lamps. Thus new, more sophisticated techniques are required. And finally and perhaps more importantly an increasingly competitive market and increasing consumer interest require better quantitative knowledge than ever before in order to assure a fair technical basis for intelligent buying decisions.

With these increasing modern demands put on radiometric and photometric systems, it has become increasingly clear that the answers to photometric problems would have to come from more detailed understanding of radiometric questions. Fortunately, these new demands have coincided with the development of radiometry, so that radiometry is in a position to contribute in a very substantial way to the further development of photometric measurements. In addition, of course, radiometry is applicable to a much wider variety of fields where the response of the human eye is not a factor, such as meteorology, photography, photobiology, photochemistry, astronomy, atmospheric physics and a variety of military needs. Moreover, increasing concern over the pollution of our environment is placing new demands on radiometric measurements.

Although there are many notable differences between radiometry and photometry, the present status of both can be characterized by two comprehensive statements:

(1) Five percent accuracy is difficult to achieve in both fields and is realized only by experts.

(2) One percent accuracy is very rare indeed and is realized only in a few laboratories and in a few types of measurements within these laboratories.

TECHNICAL COMMUNITY

The Optical Radiation program should permit NBS to move much more rapidly and effectively toward the radiometric and photometric capability presently required by technology in the U.S. In addition the anticipation of future needs must also play an increasing role in the program. That is, the effectiveness of NBS in these areas will depend ultimately on its analysis of the most pressing national problems both in radiometry and photometry. Such analysis will require, in turn, strong interaction with the technical community. Among the activities projected for increased attention are:

(1) Increased NBS contributions to the technical literature, (2) less formal publication such as this news column, (3) inquiries initiated by NBS, both to key individuals in science and industry and to conferences of these leaders, (4) questions directed to NBS by present and potential users of optical radiation standards and other technical services. Those with optical radiation problems are thus strongly encouraged to raise these problems with the Optical Radiation Section of NBS. Such questions, particularly at this time, can play a key role in the future NBS program.

INFORMAL CONFERENCES ON THE DEFINITION OF PRESENT PROBLEMS AND NATIONAL NEEDS IN RADIOMETRY AND PHOTOMETRY

NBS has been asked to bring together, for informal meetings, representatives of laboratories making radiometric and photometric measurements, manufacturing instruments, or performing secondary calibrations. NBS is considering a series of one day meetings this year. The basic purpose is to try to reach a consensus on the most pressing problems facing radiometry, both immediately and looking ahead a few years. An auxiliary purpose will be the exchange of technical information on precise radiometric measurements. The NBS radiometry program will be reviewed and areas of possible expansion of effort explored. Those attending these meetings will be expected to participate actively in discussions directed toward arrival at a consensus.

Topics being considered for early meetings are: new calibrations required, detector needs and problems, application and testing of light-emitting-devices, and space and atmospheric radiometry.

Inquiries concerning participation in this program should be directed to Dr. Bruce Steiner, Optical Radiation Section, National Bureau of Standards, Washington, D.C. 20234.

STANDARDS AND CALIBRATION

BROADCAST OF NEW TIME SCALE

Since 1967 the second has been defined in terms of an atomic transition, while time scales in general use are based on the rotation of the earth. This has resulted in the dissemination of a compromise time scale arrived at by international agreement through the International Radio Consultative Committee, and maintained by the International Bureau of Time (BIH). This scale, known as Coordinated Universal Time (UTC), presently operates with a frequency offset from the atomic scale of -300×10^{-10} to approximately agree with the rotation of the earth. Occasional step adjustments in time of 0.1 second are also made to compensate for unpredictable variations in the earth's rate of rotation.

To avoid the disadvantages of having an offset frequency and fractional second step adjustments, the UTC time scale will change on 1 January 1972. The new UTC scale will operate with no[1] frequency offset, thus providing time intervals that are exactly one second long. The scale will continue to keep in approximate agreement with earth time, known as UT1, by step adjustments of exactly one second occurring about once per year. There will be a preference of adjustments on the 1st of January and July. In any case the new UTC scale should not differ from UT1 by more than 0.7 second.

In the U.S., therefore, the NBS standard broadcast services of WWV, WWVH, and WWVL will be changed to have zero offsets in their carrier and modulation frequencies and time signals. At 00 hours on 1 January 1972, UTC will be reset a fraction of a second, sufficient to give the new UTC scale an initial difference of an integral number of seconds (probably 10.000 seconds late) with respect to International Atomic Time (IAT) as maintained by the BIH. UTC is now about 9 seconds late compared to IAT, and during the next year the difference will probably increase to about 10 seconds; thus, the reset should be only a few hundred milliseconds. Thereafter, the difference between UTC and IAT will always be an integral number of seconds. The difference between UT1 (not UT2) and the broadcast signal will also be given after 1 January 1972, probably with a resolution of 0.1 second.

STANDARD FREQUENCY AND TIME BROADCASTS

High-frequency radio stations WWV (Fort Collins, Colo.) and WWVH (Maui, Hawaii) broadcast time signals on the Coordinated Universal Time (UTC) system as coordinated by the Bureau International de l'Heure (BIH), Paris, France. The NBS time scale, UTC(NBS), and the U.S. Naval Observatory time scale, UTC(USNO), are jointly coordinated to within ±5 microseconds. The UTC pulses occur at intervals that are longer than one coordinated second by 300 parts in 10^{10} during 1971, due to an offset in carrier frequency coordinated by BIH. To maintain the UTC scales in close agreement with the astronomers' time, UT2, phase adjustments are made at 0000 hours Greenwich Mean Time (GMT) on the first day of a month as announced by BIH. *There will be no adjustment made on November 1, 1971.*

The low-frequency radio station WWVB (Fort Collins, Colo.) broadcasts seconds pulses without offset to make available to users the standard of frequency so that absolute frequency comparisons may be made directly, following the Stepped Atomic Time (SAT) system. Step time adjustments of 200 ms are made at 0000 hours GMT on the first day of a month when necessary. BIH announces when such adjustments should be made in the scale to maintain the seconds pulses within about 100 ms of UT2. *There will be an adjustment made on November 1, 1971. The seconds pulses emitted from WWVB will be retarded 200 ms.*

NBS obtains daily UT2 information from forecasts of extrapolated UT2 clock readings provided by the U.S. Naval Observatory with whom NBS maintains close cooperation.

[1] In both the August and September versions of this announcement, which is being repeated because of its impact on potential users, the word "a" was erroneously run instead of "no".

PIEZOELECTRIC *Continued*

to 2/3 the original value and specimens cut from it with coordinate axes identified as follows: *1*, in the direction of rolling; *2*, perpendicular to it and in the film plane; and *3*, perpendicular to the film. After rolling the PVC specimens were found to have a piezoelectric modulus of 0.2 to 0.7 V m^{-1}/N m^{-2}. The piezoresponse was highly anisotropic, in that only slight response was found for the other axis in the plane of the film.

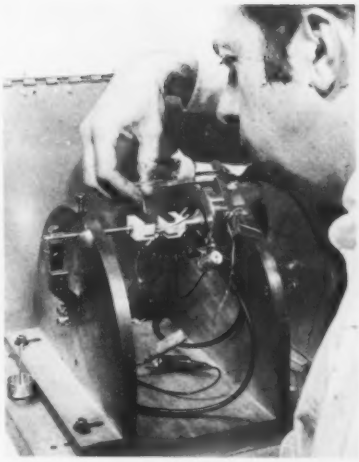
PVF as received from the manufacturer, on the other hand, exhibited no piezoelectric effects; their absence results from its being cast as a sheet and not being rolled. When rolled in the laboratory to about a quarter of its original thickness it exhibits modest piezoproperties when excited in the direction of the stressing (0.1-0.2 V m^{-1}/N m^{-2}). Unlike the PVC, its piezoresponse is greater to excitation in the direction in the film plane perpendicular to the original stressing, reaching 1.0 V m^{-1}/N m^{-2}.

Present investigations are directed at still more effective methods of polarizing polymer materials and the creation of other effects, such as pyroelectricity.

[1] Cohen, J. and Edelman, S., Piezoelectric effect in oriented polyvinylchloride and polyvinylfluoride, J. Appl. Phys. (July 1971).

[2] Edelman, S., Roth, S. C. and Grisham, L. R., Electrical generation of motion in elastomers, Shock and Vibr. Bull. **39**, Part 2, 1-9 (1969) and Piezoelectric phenomena in elastomers, Nat. Bur. Stand. (U.S.), Tech. News Bull. **53**, 31-32 (Feb. 1969).

[3] Edelman, S., Grisham, L. R., Roth, S. C., and Cohen, J., Improved piezoelectric effect in polymers, J. Acous. Soc. Am. **48**, 1040-1043 (Nov. 1970).



Julius Cohen connects a clip lead to a tiny acceleration transducer cut from a sheet of treated polyvinylchloride. The apparatus holding it will apply axial vibration to one end of the transducer so that its piezoresponse can be measured.

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